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PHYSIOLOGY AT HARVARD

BY

WILLIAM TOWNSEND PORTER, M.D.

ASSOCIATE PROFESSOR OF PHYSIOLOGY IN THE
HARVARD MEDICAL SCHOOL

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PHYSIOLOGY AT HARVARD

I

THE LABORATORY METHOD

Introduction

The new method of teaching physiology proposed in the *Boston Medical and Surgical Journal*,[1] December 29, 1898, and more fully explained in the *Philadelphia Medical Journal*,[2] September 1, 1900, was adopted by the Harvard Medical School in 1899. The experience of two years has shown this method to be sound in theory and feasible in practice. It is my present purpose to state how far we have gone upon this new road. Such an account will provide the students in the Harvard Medical School with a working plan and will be useful to physiologists and to others who have to do with the teaching of the biological sciences. The present total lack of such precise accounts hinders progress. It is almost impossible to find out just what the individual student receives in the various universities. The experience of one university is not accessible to others.

[1] Porter, W. T.: The teaching of physiology in medical schools, *Boston Medical and Surgical Journal*, December 29, 1898, pp. 647–652.

[2] Porter W. T.: The teaching of physiology, *Philadelphia Medical Journal*, September 1, 1900.

Old and New

The traditional method of teaching physiology consists of a systematic course of lectures. The new method consists of a systematic course of experiment and observation by the student himself. In the old method the student rests upon the dictum of the professor and the text-book. In the new he is thrown upon the fundamental experiments done with his own hands. In the old his experiments illustrate the lecture. In the new the lecture discusses his experiments and collates them with the work of others. The old insensibly teaches men to depend upon authority, but the new turns them to nature.

Ways and Means

The new method requires:

1. Printed accounts of the fundamental experiments and observations in physiology, taken from the original sources, and arranged in the most instructive sequence.

2. Accessory data grouped about the fundamental experiments. Consider, for example, the function of the roots of spinal nerves. The fundamental experiment here is Johannes Müller's well-known section and stimulation of the nerve roots. The accessory data are such of the observations and opinions of his successors as are necessary to give a clear picture of the present state of knowledge of this subject. The accessory data as well as the fundamental experiments should be taken as directly as possible from the

original sources, and the reference should be given in each case.

3. Apparatus of precision designed with the utmost simplicity upon lines that permit its manufacture in large quantities at small cost.

It should be observed that this method serves for the instruction of all students from beginners to those engaged in research. The beginner performs the fundamental experiment in each group and studies the accessory data. If certain fundamental experiments require too much time, the beginner limits himself in these cases to a study of the original protocol. The advanced student performs the fundamental experiments and as many of the accessory experiments as may give him the special training he desires. The research student has before him the classical observations and original sources of the problem he has chosen.

It should be noticed, also, that the new need not violently dislocate the old method of instruction, but that it may replace it chapter by chapter as the means and the energy of the instructors permit. Harvard experience justifies this statement. Collections of fundamental and accessory experiments in the physiology of muscle, nerve, the circulation, the central nervous system, the skin, and physiological optics have been printed.[1]

[1] Porter, W. T.: An Introduction to Physiology. Part I. The Physiology of Muscle and Nerve, pp. 1–235. Second Edition, January, 1901. Part II. The Circulation, pp. 237–314. Parts I and II are bound together in green cloth. Part III. The Spinal Cord and Brain, *in preparation*. Meanwhile the principal experiments upon the cord and brain, together with those upon cutaneous sensations, have been printed in Experi-

These collections are being completed and improved as rapidly as possible, and the data for the remaining chapters are being brought together. In its final form this matter will constitute "A Laboratory Text-book of Physiology."[1]

The Harvard Physiological Apparatus has been especially devised for the laboratory teaching of large numbers of students. The latest models of this apparatus are distinguished by their simplicity of design, sound workmanship, and low cost.

With this equipment two hundred and ten students in the last collegiate year performed physiological experiments in the laboratories of the Medical School five mornings every week during four months. The new method was employed in the physiology of muscle and nerve, the circulation and the skin, and in physiological optics. A part of the physiology of the central nervous system was taught by the new method, the remainder by the old. The physiology of respiration and of other fields for which the necessary experiments and accessory data were not ready was taught entirely by the traditional system of lectures with demonstrations.

During the present year, 1901–1902, the instruction will be as follows:

COURSES OFFERED IN 1901–1902

1. First-Year Course.
2. Advanced Course.
3. Research.
4. Summer Course.

ments for Harvard Medical Students, Second Series, 1902, pp. 1–28, Second Edition. Part IV. Physiological Optics, pp. 1–96. Bound in gray paper. Other parts in preparation.

[1] This title is copyrighted by W. T. Porter.

II

THE FIRST-YEAR COURSE

THE first-year course is required of all students. It is designed to give the general introduction to physiology that every Doctor of Medicine should possess. It is valuable also to biologists not intending to become physicians. The medical students who take this course have spent the first four months of the collegiate year in the study of anatomy, histology, and embryology. The mornings of the second four months, February, March, April, and May, are given to physiology; and the afternoons of three of these months, February, March, and April, to physiological chemistry, which is now taught in the Chemical Department.

The instruction given each student is shown in the accompanying tables, which will be followed by a description of the several exercises.

TABLE I

Showing the Instruction given Each Student in the First-Year Course

Number of Exercises.	Character of Exercise.	Hours of Instruction.
75	Laboratory experiments. Professor W. T. Porter and Drs. Cannon, Lillie, and Opitz. *Daily, except Saturday.*	180
75	Conference. Professor W. T. Porter and Dr. Cannon. *Daily, except Saturday. First to fifteenth week, inclusive.*	36
75	Written tests. *Daily, except Saturday. First to fifteenth week, inclusive.*	
50	Lectures, with demonstrations. Professor W. T. Porter and Dr. Cannon *Daily, except Saturday. Sixth to fifteenth week, inclusive.*	25
15	Special demonstrations. Professor W. T. Porter and Dr. Cannon. *Saturdays. First to fifteenth week, inclusive.*	15
15	Recitations. Professor Bowditch. *Saturdays. First to fifteenth week, inclusive.*	15
15	Recitations. In sections. Professor W. T. Porter and Dr. Cannon. *Mondays. First to fifteenth week, inclusive.*	11
50	Discussion of theses. The entire class and the Staff. *Daily, except Friday. Sixth to fifteenth week, inclusive.*	40
24	Optional lectures. Professors Bowditch and W. T. Porter, Drs. Cannon, Lillie, and Opitz. *Afternoons in May, except Saturdays.* (In 1900-1901 there were 37 optional lectures.)	18
	Thesis. Written by each student from the original sources.	
	Reading of investigations. The reading of one or more investigations in the original source and the discussion of these when the theses upon the same subjects are discussed.	
	Special experimental work. Optional during the fifteenth and sixteenth weeks, for selected students.	

TABLE II

Program of First-Year Course

SECOND HALF-YEAR.				
Physiology. February 8 to March 15.				
Monday.		Tuesday. Wednesday. Thursday. Friday.	Saturday.	
9-9.30	Conference. Room A.	Conference. Room A.		
9.30-9.50	Written Test. Room B.	Written Test. Room B.		
9.50-12	Laboratory Experiments. Room B.	Laboratory Experiments. Room B.	10-11	Recitation. Room A.
12-1	Recitation. In Sections. Room B.		11-12	Demonstration. Room A.
March 17 to May 31.				
9-9.30	Lecture. Room A.	Lecture. Room A.	9-9.45	Discussion of Theses. Room A.
9.30-10	Conference. Room A.	Conference. Room A.		
10-10.20	Written Test. Room B.	Written Test. Room B.	10-11	Recitation. Room A.
10.20-12.15	Laboratory Experiments. Room B.	Laboratory Experiments. Room B.		
12.15-1	Recitation. In Sections. Room B.	Discussion of Theses. Room A.	11-12	Demonstration. Room A.
June 1 to June 7.				
Laboratory Experiments. Room B.				

Instructions to Students

Five weeks before the beginning of the course the following letter is sent to each student:[1]

Form A.

Department of Physiology,
Harvard Medical School,
January 2, 1902.

Dear Sir: —

Since many of the laboratory experiments in physiology require two men for their successful performance, the class will be divided into pairs. Students may work with whom they please, provided those desiring to work together give written notice to Professor W. T. Porter not later than February 1. Where no preference is expressed the pairing will be made from an alphabetical list. The distribution of the pairs at the laboratory desks will be posted on the bulletin board February 6. Students are advised to provide themselves with the following articles:

1. A dissecting case, including scissors, one large and one small forceps, and a seeker.
2. A small towel.
3. A piece of cotton cloth about 40 × 40 cm.
4. A microscope with a hinged standard allowing the stage to be tilted to a perpendicular position. One member of each pair may rent a microscope by applying to the Department of Histology. Students now using a microscope of the required kind may there arrange to keep it and their microscope locker during the second half-year.

[1] Letters, lists of apparatus, and similar matter for the use of students are printed upon the Rotary Neostyle.

5. The pamphlet entitled "Physiology at Harvard."

6. The Physiological Laboratory Note-book.

7. The Introduction to Physiology, Parts I and II, bound together in cloth. To be had from W. B. Clarke Company, corner of Park and Tremont Streets, Boston.

8. Experiments for Harvard Medical Students, Second Series, bound in gray paper.

9. The Introduction to Physiology, Part IV, bound in gray paper.

10. The Physiological Thesis Book.

Articles 1, 2, 3, 5, 6, 8, 9, and 10 are sold by the Co-operative Society.

First-year medical and dental students will meet the Staff of the Department February 8, at 9 A.M., in Room A, where they will be addressed by Professor Bowditch.

At 9.30 A.M. the students will find their desks in Room B. Each desk bears the names of the owners upon a printed slip. Each student will receive a key to the locker in his desk. For each key a deposit of one dollar will be required, to be refunded when the key is returned.

Within the cupboard and drawers of the locker will be found the apparatus necessary for the first work of the course, together with a printed list of the apparatus (see Appendix, Form G, page 62). Articles marked * will be found in the small wooden boxes. The list should be verified and signed by each student. This receipt will be retained by the Department.

The apparatus is issued in good condition, and students will be held responsible for its return in good condition. The cost of cleaning, repairing, or replacing articles which become damaged will

be charged to the students to whom they were issued. A list of the articles liable to be broken beyond repair is posted in the laboratories, with the cost opposite each (see Appendix, Form J, page 66). Students desiring additional apparatus must present a signed requisition for the desired article (see Appendix, Form F, page 61).

Frogs and tortoises will be issued on the presentation of signed requisitions. Students using more than the average number of animals will be charged ten cents for each additional medium-sized frog, and twenty-five cents for each large frog and each tortoise.

Every charge will be divided equally between the two members of the pair represented by the name on the requisition.

You are advised to keep this letter for reference.

Very truly yours,

W. T. Porter.

Laboratory Experiments

In the laboratory the student works fourteen hours a week during six weeks, and ten hours a week during the ten other weeks of the course.

Pairing. — Many of the experiments cannot be done by one person alone. Others are performed more rapidly and with better results by two workers than by one. Moreover, discussion and mutual criticism are valuable. The class is therefore divided into pairs. Students are urged to select their comrades for themselves. Those who fail to choose are paired by lot. The pair usually decides to divide the experimental work so that upon one day the preparation of the

frog, or other material, shall fall to one student, while the arrangement of the apparatus shall fall to the other; the next day, these duties are exchanged.

Distribution of Time. — The sixteen weeks of experimentation are divided as follows:

February 8–March 14. Muscle and nerve.
March 17–25. Spinal cord and brain.
March 26–27. Cutaneous sensations.
March 28–April 1. Taste, smell, hearing.
April 2–8. Physiological optics.
April 9–11. Vision.
April 13–19. Recess.
April 22–May 2. Digestion, absorption, lymph, blood, secretion, respiration, metabolism.
May 5–29. Circulation.
May 30. Memorial Day — a holiday.
June 2–7. Practical examination.

The physiology of muscle and nerve heads the list, for the logical reason that contractility and irritability are the primary attributes of living tissues and should be studied first, and for the practical reason that no field has been so thoroughly worked as this and none is so well adapted to train the beginner in physiological technique and the physiologist's habit of thought.

It will be observed that the time given to this subject is relatively greater than that given to any of the others. The greater training power of the physiology of muscle and nerve accounts for this in part. But the student's lack of skill and knowledge is the chief cause. When the stu-

dents begin the study of muscle and nerve they are as a rule unacquainted with experimentation upon living tissues. During the first two weeks they are slow and awkward. During the third week a remarkable change begins. At the fifth week it may be said without exaggeration that most of the students are rapid and fairly accurate experimenters. The experiments upon muscle and nerve, which require the mornings of five weeks at the beginning of the course, could at the end of the course be easily done in three. The experiments upon the circulation, which require four weeks in their present position, would require at least six if placed at the beginning of the course.

It should be said, further, that the work upon muscle and nerve includes certain experiments that are commonly taught under the heading of the nervous system.

The students who enter the physiological course have already studied the special anatomy of organs the structure of which would otherwise be described by the physiologist. This rational preparation materially shortens the time required for certain chapters in physiology.

The space assigned the vegetative functions is small because the laboratory work in the chemistry of the carbohydrates, fats, proteids, bone, cartilage, muscle, salivary glands, stomach, pancreas, bile, blood, milk, and urine is pursued at present in the Department of Chemistry.

Experiments Performed. — Following is a complete list of the experiments performed. Students are not permitted to pass to a new experiment

until the one in hand has been performed to the satisfaction of the instructors. Only work well done is accepted.

Physiology of Muscle and Nerve

Methods of Electrical Stimulation. — The preparation of the gastrocnemius muscle, p. 4. The nerve-muscle preparation, p. 6. Galvani's experiment, p. 12. Polarization current, p. 25. Make and break induction currents as stimuli, p. 40. Tetanizing currents, p. 42. Exclusion of make or break current, p. 43. Unipolar induction, Experiments 1 and 2, pp. 44 and 45.

Stimulation of Muscle and Nerve. — Opening and closing contraction, p. 61. Changes in intensity of stimulus, Experiments 1 and 2, pp. 62 and 63. Polar stimulation of muscle, Experiment 5, p. 68. Tonic contraction, p. 70. Physiological anode and cathode in rectus muscle, p. 72. Law of contraction, p. 75. Changes in irritability, Experiment 1, p. 79. Changes in conductivity, p. 82. Stimulation of human nerves, p. 89. Stimulation of motor points, p. 92. Polar stimulation of human nerves, p. 93. Reaction of degeneration, p. 97. Influence of duration of stimulus, Experiment 2, p. 101. Rhythmic contraction, Experiment 1, p. 103. Polarization current, Experiment 1, p. 106. Polar fatigue, p. 108. Polar inhibition by the galvanic current, Experiment 1, p. 114. Effect of the angle at which the current lines cut the muscle fibres, p. 118. Polar stimulation by the induced current, Experiment 2, p. 120.

Chemical and Mechanical Stimulation. — Effect

of distilled water, p. 124. Strong saline solutions, p. 125. Drying, p. 125. Normal saline, p. 126. Importance of calcium, p. 126. Constant chemical stimulation may cause periodic contraction, p. 126. Mechanical stimulation, p. 127.

Irritability and Conductivity. — The independent irritability of muscle; curare experiment, p. 132. Irritability and conductivity are separate properties of nerve, Experiment 1, p. 134. Minimal and maximal stimuli; threshold value, p. 137. Summation of inadequate single stimuli, p. 138. The same nerve fibre may conduct impulses both centripetally and centrifugally, Experiment 1, p. 144. Speed of nerve impulse, p. 146.

The Electromotive Phenomena of Muscle and Nerve. — Demarcation current of muscle, Experiment 1, p. 150 (omit last three lines). Uninjured muscle, p. 153. Stimulation by demarcation current, Experiment 1, p. 153. Measurement of electromotive force of demarcation current, compensation method, p. 158. Demarcation current of nerve, p. 159. Action current of muscle, Experiments 1 (rheoscopic frog) and 2, p. 166. Action current of heart, Experiments 1 and 2, p. 173. Action current of nerve; negative variation, Experiment 1, p. 178. Secretion current from mucous membrane, p. 183.

The Change in Form. — The duration of the several periods, p. 196. The excitation wave, p. 199. The contraction wave, p. 201. Influence of load on height of contraction, p. 204. Influence of temperature on form of contraction, p. 205. Superposition of two contractions, p. 209. Superposition in tetanus, p. 210. Muscle sound, Ex-

periments 1, 2, and 3, pp. 211–212. Relation of shortening in a single contraction to shortening in tetanus, Experiments 1, 2, and 3, pp. 215–217. Graduation of isometric spring, p. 218. Isometric contraction, p. 219. Artificial tetanus of human muscle, p. 221. Natural tetanus of human muscle, Experiments 1 and 2, p. 221. Spontaneous contractions of smooth muscle, p. 221. Simple contraction of smooth muscle, p. 222. Tetanus of smooth muscle, p. 223. Influence of load on work done, p. 223. Absolute force of muscle, p. 224. Total work done; the work adder, p. 224. Time relations of developing energy, p. 226. Elasticity and extensibility of a metal spring, p. 229. Of a rubber band, p. 230. Of skeletal muscle, p. 230. Fatigue of skeletal muscle of frog, Experiments 1 and 2, p. 232. Fatigue of human skeletal muscle, Experiment 1, p. 233.

Students better prepared than the average will finish the experiments on muscle and nerve in less than the average five weeks. Such men may perform the additional experiments on muscle and nerve provided below.

Additional Experiments on Muscle and Nerve

[To be begun only in case the first list is finished in less than the prescribed five weeks. These additions comprise the experiments in the Introduction to Physiology, Part I, not included in the first list.]

Methods of Electrical Stimulation. — Surface tension, p. 15. Surface tension altered by elec-

trical energy, p. 16. The cell, p. 21. Electrolysis of potassium iodide, p. 27. Graduation of the electrometer, p. 28. Magnetic induction, p. 30. Magnetic field; lines of force, p. 33. To produce electric induction, the lines of magnetic force must be cut by the circuit, p. 33. Electromagnetic induction, p. 33. Make and break induction, p. 34. The inductorium, pp. 35–37. Empirical graduation of inductorium, p. 38. The extra currents at the opening and closing of the primary current, Experiments 1 and 2, pp. 41–42. Induction in nerves, p. 43. Unipolar induction, Experiments 3, 4, 5, and 6, pp. 45–49. Changes in intensity of stimulus with indirect stimulation, Experiments 1 and 2, pp. 63–64. Polar stimulation of muscle, Experiments 1, 2, 3, and 4, pp. 65–67. Polar stimulation in heart; monopolar method, p. 74. Changes in irritability, Experiments 2 and 3, pp. 79–81. Conductivity is diminished by strong or protracted currents in the cathodal as well as in the anodal region, p. 85. Galvanotropism, p. 98. Influence of duration of stimulus, Experiments 1, 3, 4, and 5, pp. 100–102. Rhythmic contraction; skeletal muscle, p. 104. Continuous galvanic stimulation of nerve may cause the periodic discharge of nerve impulses, pp. 105–106. Polarization current; positive variation, p. 107. Opening and closing tetanus, Experiments 1, 2, 3, and 4, pp. 108–110. Polar excitation in injured muscle, p. 112. Polar inhibition in veratrinized muscle, p. 116. Stimulation affected by the form of the muscle, p. 117. The induced current, Experiments 1, 3, and 4, pp. 119–121.

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tive variation, p. 180. Current of action in optic nerve, p. 181. Errors from unipolar stimulation, p. 183. Negative variation of secretion current, p. 184. Electrotonic currents, p. 186. Negative variation of electrotonic currents ; positive variation (polarization increment) of polarizing current, p. 188. The electrotonic current as a stimulus, p. 191. Paradoxical contraction, p. 191.

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[1] Experiments for Harvard Medical Students. Second Series, pp. 1–20.

action, p. 8. Removal of cerebral hemispheres, p. 8. Posture, "brainless" frog, p. 9. Balancing experiment, p. 10. Retinal reflex, p. 10. Croak reflex, p. 10. Apparent purpose in reflex action, Experiments 1, 2, and 3, p. 12. Reflex time, p. 13. Reaction time, p. 13. Reaction time with choice, p. 14. Inhibition of reflexes through peripheral afferent nerves, p. 15. Inhibition through central afferent paths; the optic lobes, Experiments 1 and 2, p. 16. The roots of spinal nerves, p. 17. Localization of movement at different levels of the spinal cord, p. 18. Distribution of sensory spinal nerves, p. 19. Muscular tonus; Brondgeests's experiment, p. 20.

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[1] Ibid., pp. 21–28.

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[1] Introduction to Physiology, Part IV, Physiological Optics, pp. 1–99.

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VISION, DIGESTION, ABSORPTION, LYMPH, BLOOD, SECRETION, RESPIRATION, METABOLISM

[Experiments to be announced later.]

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[1] Introduction to Physiology, Part II, pp. 239–314.

p. 257. Graphic record of ventricular contraction, p. 258. All contractions maximal, p. 258. Staircase contractions, p. 259. The isolated apex; Bernstein's experiment, p. 259. Rhythmic contractility of heart muscle, p. 260. Constant stimulus may cause periodic contraction, p. 260. The inactive heart muscle still irritable, p. 261. Refractory period; extra-contraction; compensatory pause, p. 261. The transmission of the contraction wave in the ventricle; Engelmann's incisions, p. 262. The transmission of the cardiac excitation from auricle to ventricle; Gaskell's block, Experiments 1, 2, and 3, pp. 263 and 264. Tonus, p. 265. The influence of "load" on ventricular contraction, p. 265. The influence of temperature on frequency of contraction, p. 266. The action of sodium, calcium, potassium in heart muscle, pp. 266–268. The heart sounds, Experiments 1, 2, 3, and 4, pp. 269–271.

The Pressure-Pulse. — Frequency, p. 271. Hardness, p. 272. Form, p. 272. Volume, p. 273. The pressure-pulse in the artificial scheme, p. 273. The human pressure-pulse curve, Experiments 1 and 2, pp. 274–275. Low tension pressure-pulse, Experiments 1 and 2, p. 277. Pressure-pulse in aortic regurgitation, p. 278. Stenosis of the aortic valve, p. 279. Incompetence of the mitral valve, p. 280. The volume pulse, p. 280.

The Innervation of the Heart and Blood-Vessels. — Preparation of the sympathetic, p. 283. Action of the sympathetic on the heart, p. 284. The preparation of the vagus nerve, p. 286. Stimulation of cardiac inhibitory fibres in vagus trunk, p. 287. Effect of vagus stimulation on the auriculo-

ventricular contraction interval, p. 289. Irritability of the inhibited heart, p. 289. Intracardiac inhibitory mechanism, p. 290. Inhibition by Stannius ligature, p. 290. Action of nicotine, p. 291. Atropine, p. 292. Muscarine, p. 292. Antagonistic action of muscarine and atropine, p. 292. Inhibitory centre of the heart nerves, p. 292. Augmentor centre, p. 294. Reflex inhibition of the heart; Goltz's experiment, p. 295. Reflex augmentation, p. 296. The bulbar vasomotor centre, Experiments 1 and 2, pp. 296 and 297. The vasomotor functions of the spinal cord, Experiments 1, 2, and 3, p. 298. Effect of destruction of the spinal cord on the distribution of the blood, p. 299. The vasomotor fibres leave the cord in the anterior roots of spinal nerves, Experiments 1 and 2, p. 300. Vasoconstrictor fibres in the sciatic nerve, p. 302. Vasodilator nerves, Experiments 1 and 2, p. 303. Reflex vasomotor actions, p. 304.

Apparatus

A complete list of the articles used in the first-year course, including the additional experiments, page 15, will be found in the Appendix, pages 53–61.

The desk assigned each pair of students is 155 cm. long and 61 cm. wide. A ledge 7 cm. high guards the farther side. At one end are placed a locker 35 cm. wide, and two drawers; a single lock secures the three. Not all the apparatus used in the course can be placed in the locker and drawers at one time. That used in

the earlier chapters is issued first (see Appendix, Form G, page 62). From time to time, articles of the first issue no longer in use are returned to the instructors (see Appendix, Form I, page 65).

The department finds it advisable to maintain a stock of apparatus large enough to enable broken articles to be replaced at once from the reserve. Thus the student is not delayed while repairs are making; moreover, the repairing for the entire course can then be done in the summer, after the instruction is finished. The expense, per instrument, is thereby diminished.

Laboratory Note-Book

Each student is required to keep in a laboratory note-book an account of his own experiments and observations. The details of the experiment given in the laboratory publications should of course be omitted. Where the experiment includes a graphic record, such as a muscle curve or a curve constructed upon coördinate paper, the record should be fastened in the laboratory note-book with gummed paper. Diagrams should be employed whenever necessary, but time should not be spent in needlessly detailed drawing of apparatus. The note-books will be collected every Friday and examined by the instructors.

Conference

The conferences are held in Room A for half an hour five times a week during fifteen weeks. They are devoted to questions and explanations

concerning the work of the course, and are in fact a combination of recitation and lecture. The matters discussed are suggested by the written tests and by the questions placed by the students in question boxes, one of which is set in each laboratory.

Written Tests

The written tests are exercises of twenty minutes' duration, held daily during fifteen weeks. Two questions are asked, upon any part of the previous work. In all cases the student is required to cite the experimental evidence for his statement. The answers are written upon ruled paper of uniform size, 24.5 × 19.5 cm., printed as follows:

Form B.

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY.

Name.................................... Date .... 190.....

Desk.................................... Room......................................

Each day's papers are filed in a case, in which a pigeon-hole is provided for each student. In the same pigeon-hole are placed in their turn the student's thesis, laboratory note-book, and final examination papers, constituting a complete record of his work.

The written tests form a most valuable method of instruction. They teach the student to state with precision and brevity the experimental evidence for many of the fundamental conclusions

in physiology. At the close of the first month of instruction men whose work the written tests show to be poor are personally consulted regarding their difficulties, often to their great benefit.

The following questions illustrate the written tests:

State experiments to prove where stimulation begins on closure of the galvanic current. Explain the difference between the stimulating electrodes and the physiological anode and cathode in stimulation of human nerves. What is the reaction of degeneration? What chemical changes take place in dying muscle? Draw the curve expressing the absolute force of muscle from the beginning to the end of the phase of rising energy and state how it is obtained. Mark on the intraventricular pressure-curve the moment of opening and closing of the mitral and aortic valves. Give the experimental basis for an explanation of the auriculo-ventricular interval. Describe the action of the vagus nerve upon the heart. Give evidence to show that afferent impulses are transmitted by the posterior roots of spinal nerves. What evidence is there that the fibres passing through the white ramus communicans arborize about a sympathetic cell? Cite experiments to prove that the crystalline lens changes its shape in accommodation. Give evidence that the semicircular canals are concerned in equilibrium. State the evidence for the existence of hot and cold "spots" on the skin. State the difference between voice and tone. Give a brief account of the digestion of fat. Give proof of the existence of internal secretion. What proof exists

that hæmoglobin and oxygen are in loose chemical combination in the blood? How may a nitrogen equilibrium be established?

Special Demonstrations

A special demonstration is given every Saturday during fifteen weeks. The subjects during 1902 will be as follows:

Feb. 15. (1) Surface tension altered by electrical energy.
(2) Extra currents at the opening and closing of the primary current.
March 1. Reaction of degeneration in man.
" 8. Action current of the human heart.
" 15. Electromotive properties of an "artificial nerve."
" 22. (1) The action of the sympathetic on the smooth muscle of the hairs.
(2) The pigeon deprived of cerebral hemispheres.
" 29. Stimulation of the cerebral cortex.
April 5. The pigeon with severed external semicircular canals.
" 12. The innervation of the sphincter of the iris.
" 26. Movements of the stomach and intestines.
May 3. The flow of lymph from the thoracic duct.
" 10. The action of the chorda tympani and the sympathetic nerves on secretion by the submaxillary gland.

May 17. The action of the vagus and the superior laryngeal nerves upon the respiratory movements.

" 24. (1) The action of the valves in the ox heart.
(2) The inhibition of the mammalian heart.

" 31. (1) The action of the depressor nerve upon the vasomotor centre.
(2) The vasomotor fibres in the cervical sympathetic.

The demonstrations are made to not more than ten students at one time. Care is taken that every student shall see the experiments clearly.

Recitations

Two recitations are given weekly during fifteen weeks; for one of these the class is divided into sections, each in charge of one instructor. The recitations are not examinations; their only purpose is instruction. The questions are asked in an order that will systematically develop the subject treated.

Theses and the Reading of Investigations

Each student is required to write a physiological thesis, the material for which must be taken directly from the report of the original investigators. The subjects chosen are as a rule such as will supplement the instruction given in other

ways. In 1902 fifty-six theses will be discussed by the class.

Before the beginning of the course the following letter of instructions is addressed to each student:

Form C.

INSTRUCTIONS FOR THESIS

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
BOSTON, February 1, 1902.

DEAR SIR: —

In the first-year course in physiology, each student is required to write a physiological thesis, the material for which must be taken directly from the original investigations. As many of the investigations are in German or French, you are requested to state upon the enclosed card (Form D) whether you can read one or both of these languages. On pages 33–37 of the pamphlet entitled "Physiology at Harvard" you will find a list of subjects for theses which will be discussed by the class in 1902, and a second list of subjects for theses to be written but not discussed during the present year. Your record during your first term in the Medical School assigns you to the {first / second} list. Five weeks before your thesis is due, you will receive an envelope bearing the subject of the thesis and containing a reference card. Upon one side of the card is a list of the investigations on the subject of the thesis; upon the other, a list of the chief physiological journals and the names of the Boston and Cambridge libraries which contain them. Further information may be had from the "List of periodicals, etc., in the principal libraries of Boston and vicinity," published by the Trustees of the

Boston Public Library. Your receipt for the reference card will be taken (Form E). The card must be returned when the thesis is handed in. Your assistance in the correction of errors and omissions in the references will be much appreciated.

The thesis should not exceed two thousand words. It should be written with ink in a Physiological Thesis Book. Every statement not the writer's own must be accompanied by a reference to the original source, giving author's name, name of journal or title of book, year of publication, number of volume, and the page upon which the statement appears. The thesis should begin with a brief outline of the problem and the way in which investigators have attacked it, and should end with a summary of the results attained.

Students whose rank entitles them to read theses will also be required to acquaint themselves with one investigation upon each of three other subjects in the list to be discussed by the class. The references for these will be found upon Form E, in the envelope containing the references for the thesis. Each thesis subject, therefore, will be studied in full by the author of the thesis and in part by three disputants. When the thesis is read, the three students who have each prepared one investigation upon that subject will open the discussion.

Very truly yours,

W. T. Porter.

Form D.

Harvard Medical School,
Boston,...............................

Dear Sir: —

I $\left\{\begin{matrix}\text{cannot}\\ \text{can}\end{matrix}\right\}$ read French and German. My preference of subjects for a thesis is as follows:

1. ....

2. ....

3. ....

Very truly yours,

....

Form E.

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
BOSTON, February 3, 1902.

I have received this day the references for the thesis on..

This thesis, together with the reference card, is to be delivered to Professor W. T. Porter not later than..

I have also been assigned the following investigations to be prepared for discussion upon the designated days.

DATE.	SUBJECT.
....	....
....	....
....	....
....	....
....	....
....	....

(Signed)..............................

This receipt is issued in duplicate. The student will retain one copy.

THESES TO BE DISCUSSED IN 1902

March	18.	The functions of the cell nucleus.
"	19.	Phagocytosis.
"	20.	Influence of light on protoplasm.
"	21.	Chemotaxis.
"	22.	Bacteria in health.
"	25.	Nature of the nerve impulse.
"	26.	Nature of muscular contractility.
"	27.	Ciliated epithelium.
"	28.	Nerve cells in rest and activity.
"	29.	Trophic nerves.
April	1.	Cross-suturing of nerves.
"	2.	Sensory areas in the cortex of the brain.
"	3.	Aphasia.
"	4.	Reflexes from sympathetic ganglia.
"	5.	Nerve-cell connections of the splanchnic nerves.
"	8.	Cerebral activity and circulation.
"	9.	The neuron theory.
"	10.	Accommodation of the eye.
"	11.	Color blindness.
"	12.	Function of the semicircular canals.
"	22.	Functions of the epiglottis.
"	23.	Vowel sounds.
"	24.	Muscle leverage.
"	25.	Deglutition.
"	26.	Movements of the stomach.
"	29.	Autodigestion of the stomach.
"	30.	Digestion of enemata.
May	1.	(1) Absorption of fat. (2) Absorption from the peritoneal cavity.

May 2. (1) Origin of lymph.
(2) Œdema.
" 3. (1) Origin and fate of the red corpuscles.
(2) Hæmorrhage and the regeneration of the blood.
" 6. Transfusion of blood.
" 7. (1) Fibrin ferment.
(2) Physiological effects of high altitudes.
" 8. Gland cells in rest and activity.
" 9. Secretion of foreign substances in milk.
" 10. Excretion of urea.
" 13. Internal secretion of the pancreas.
" 14. Vicarious function.
" 15. Alcohol as food and stimulant.
" 16. Respiratory exchange in the lungs.
" 17. Cause of the heart-beat.
" 20. (1) Negative pressure in the ventricles.
(2) The effects of closure of the coronary arteries.
" 21. Origin of glycogen.
" 22. Origin of urea.
" 23. (1) Heat regulation.
(2) Fever.
" 24. Hibernation.
" 27. (1) Depressor nerve.
(2) Vascular conditions during sleep.
" 28. (1) Vasomotor nerves of the lungs.
(2) Massage.
" 29. Artificial parthenogenesis.

Theses to be Written but Not Discussed in 1902

Nature of voluntary muscle contraction.
Muscle twitch and tetanus.
Muscle tonicity.
Smooth muscle.
Muscle work.
Influence of heat on muscle.
Muscle fatigue.
Heat production in nerves.
Rate of nerve impulse.
Chemical stimulation of nerve.
Nerve degeneration and regeneration.
Neuromuscular spindles.
Efferent nerve fibres in posterior roots.
Localization of neurons.
Functions of the bile.
Cause of death by electric currents.
Knee jerk.
Inhibition.
Absorption of proteids.
Skin absorption.
Influence of nerves on intestinal absorption.
Phenomena of agglutination.
Estimation of hæmoglobin in blood.
Specific gravity of blood.
Secretion of foreign substances in milk.
Relation of diuresis to the circulation in the kidney.
Relations between the functions of the spleen and the pancreas.
Internal secretion of the thyroid gland.
Heat production in glands.
Mode of action of diuretics.

Water excretion by the skin.
Internal secretion of the kidney.
Secretion of bile.
Diuretic action of sodium chloride.
Innervation of salivary glands.
Physiological albuminuria.
Function of the supra-renal capsules.
Tea and coffee.
Male and female respiratory movements.
Cause of the first respiration.
Carbon dioxide excretion by skin.
The relation between high temperature and rapid respiration.
Cause of death after vagus section.
Poisoning by carbon monoxide.
Effects of compression of one lung on respiratory exchange.
Seat of respiration in the body.
First heart sound.
Relation between the heart-beat and the constituents of the blood.
Coördination of the heart-beat.
The action of the auriculo-ventricular valves.
Venous pulse.
Fibrillary contractions of heart.
Intra-auricular pressure.
Semilunar valves.
Pulse curve.
Voluntary control of heart.
Active diastole of heart.
Physiology of the embryonic heart.
Influence of gravity on the circulation.
Action of the vagus nerve on heart.
Vasodilator nerves.

Vasomotor nerves of the brain.
Accelerator nerve of heart.
Vasomotor nerves of intestine.
Cerebral circulation and intra-cranial pressure.
Vasomotor nerves of muscle.
Venomotor nerves.
Income and outgo of iron.
Coloring matters of the body.
Relation between the activity of muscle and its metabolism.
Phosphorescence.
Origin of uric acid.
Origin of the oxalic acid of the urine.
Metabolism in nerve cells.
The effect of varnishing the skin.
Compressed air.
The effect of increase in the oxygen tension.
Effect of meals on nitrogen content of urine.
Nitrogen equilibrium.
Syntheses in animal body.
Relation of urea excretion to muscle work.
Mechanism and innervation of the spleen.
Nitrogen excretion by the skin.
Nature of sugar in blood.
Regeneration of organs.
Relation between fœtal pulse and sex.

Lectures

The accessory data not already provided in the laboratory work upon muscle and nerve, the circulation, and physiological optics will be given in the conferences held during the experiments upon those subjects. The distribution of the remaining didactic exercises is shown in the accompanying calendar.

CALENDAR

Date. 1902.	Systematic Lectures.	Laboratory Experiments.	Date. 1902.
Feb. 8–Mar. 14	Muscle and nerve.	Muscle and nerve.	Feb. 8–Mar. 14
" 17	Spinal cord and brain.	Spinal cord and brain.	" 17
" 18	" "	" "	" 18
" 19	" "	" "	" 19
" 20	" "	" "	" 20
" 21	" "	" "	" 21
" 24	" "	" "	" 24
" 25	" "	" "	" 25
" 26	" "	Cutaneous sensations.	" 26
" 27	" "	" "	" 27
" 28	" "	Taste, smell, hearing.	" 28
" 31	" "	" " "	" 31
Apr. 1	Sympathetic.	" " "	Apr. 1
" 2	Cutaneous sensations.	Physiological optics.	" 2
" 3	Taste and smell.	" "	" 3
" 4	Hearing.	" "	" 4
" 7	"	" "	" 7
" 8	"	" "	" 8
" 9	Vision.	Vision.	" 9
" 10	"	"	" 10
" 11	"	"	" 11
Recess			Recess
Apr. 21	Vision.	Vision.	Apr. 21
" 22	Voice.	Digestion, absorption, lymph, blood, secretion, respiration, metabolism.	" 22
" 23	Speech.	" "	" 23
" 24	Locomotion.	" "	" 24
" 25	Digestion and absorption.	" "	" 25
" 28	" "	" "	" 28
" 29	" "	" "	" 29
" 30	" "	" "	" 30
May 1	Lymph and blood.	" "	May 1
" 2	" "	" "	" 2
" 5	" "	" "	" 5
" 6	Secretion.	" "	" 6
" 7	"	Circulation.	" 7
" 8	"	"	" 8
" 9	"	"	" 9
" 12	"	"	" 12
" 13	Nutrition, diet.	"	" 13
" 14	" "	"	" 14
" 15	Respiration.	"	" 15
" 16	"	"	" 16
" 19	"	"	" 19
" 20	"	"	" 20
" 21	Metabolism and animal [heat.	"	" 21
" 22	" "	"	" 22
" 23	" "	"	" 23
" 26	" "	"	" 26
" 27	Reproduction.	"	" 27
" 28	"	"	" 28
" 29	"	"	" 29
" 30	Holiday.	Holiday.	" 30
June 2		Practical examination.	June 2
" 3		" "	" 3
" 4		" "	" 4
" 5		" "	" 5
" 6		" "	" 6

The calendar shows that the lectures are delivered after the subject of the lecture has been studied in the laboratory. The lectures accordingly are not elementary. The elements the student has already learned from his own experiments and their accessory data. It is the function of the lecturer to discuss the student's observations and to collate them with the work of other observers. The lectures are held at nine o'clock, the hour most favorable for this purpose. They are of thirty minutes' duration. Experience shows that a carefully planned lecture of thirty minutes may be as effective as one of forty-five or sixty minutes.

Optional Lectures

During the afternoons of May optional lectures are given. The majority of these are discussions of original investigations which the lecturer himself has made. Of thirty seven optional lectures given in 1900–1901, twenty-seven were of this nature. The list for 1902 is as follows:

At 3 p.m.

May	1	Prof. Bowditch.	Growth.
"	2	" "	"
"	5	" "	Locomotion.
"	6	" "	"
"	7	" "	"
"	8	" "	Physiology of the larynx.
"	9	" "	Physiology of the larynx.

May 12	Prof. Bowditch.	Physiology of vision.
" 13	" "	" " "
" 14	" "	" " "
" 15	" "	" " "
" 16	" "	" " "
" 19	Dr. Cannon.	Movement of the food in the œsophagus and stomach.
" 20	" "	Movement of the food in the intestines.
" 21	" "	Directive influence of light on organisms.
" 22	" "	Cerebral pressure.
" 23	Dr. Lillie.	Influence of salt solutions upon certain forms of vital activity, especially ciliary and muscular movements.
" 26	Dr. Opitz.	The viscosity of the blood.

At 2 p.m.

May 15	Prof. Porter.	Path of respiratory impulse.
" 16	" "	Relation of physical development to success in public school life.
" 19	" "	Result of closure of the coronary arteries.
" 20	" "	Filling of the heart.
" 21	" "	New method for study of intracardiac pressure.

May 22	Prof. Porter.	Cause of the heart-beat.
" 23	" "	Influence of the heart-beat on the flow of blood through the walls of the heart.
" 26	" "	The pulse.

Special Experimental Work

During the last two weeks of the course students who have performed the regular laboratory work with distinction may elect to perform special experimental work. Each student is provided with a sufficiently circumscribed subject, the original sources, a method, and the necessary apparatus. With this careful preparation, many of the fundamental discoveries in the subject chosen may be repeated and the general plan of work pursued by all students of biological science acquired.

Examinations

In order to receive the degree of Doctor of Medicine the student must have demonstrated to the Department of Physiology that his training in this subject is satisfactory. The character of the student's work during the four months of his instruction counts materially toward his final grade. At the end of the term two formal examinations are held, one of which is practical, while the second is written. Candidates failing in the June examination may be re-examined in September. The practical examination, as is

natural in an experimental science, grows in importance each year. In June, 1901, the student was required to perform four out of six experiments assigned him by lot. He was examined during two half-days, receiving each day three experiments, from which he must choose two. The character of this test will be understood from the following instructions to students and the list of experiments assigned in the last examination.

Department of Physiology, Practical Examination, June 3, 4, 5, 6, 1901

NOTICE

Each student will perform four of the six experiments bearing his number. In each case he will write on one of the blank forms furnished herewith the problem selected and an account of his results. Necessary apparatus not already in the locker may be obtained by presenting a signed requisition. Where the results of the experiment are not expressed in a graphic record, they must be demonstrated to one of the instructors, who will then countersign the student's account of the experiment. Graphic records must be marked plainly with the student's name, placed in a shellacking-frame, and, at the close of the student's work, handed to one of the Staff, together with all three of the problems suggested. No student may leave his desk until his examination is finished.

PRACTICAL EXAMINATION IN PHYSIOLOGY

[Each student is required to make four of the six experiments bearing his number, and to write an account of his observations on the blank furnished herewith. Where the results of the experiments are not expressed in a graphic record they must be demonstrated to the instructor.]

1. Demonstrate polar stimulation by the galvanic current. Show the vasomotor functions of the spinal cord. Demonstrate the inhibition of reflex action in the frog. Furnish experimental evidence for an explanation of the auriculo-ventricular interval. Prove that the galvanic current stimulates during the whole time of its passage through an irritable tissue. Demonstrate the influence of load on ventricular contraction.

2. Show by diagram the method of determining the size of a retinal image. Demonstrate that the nervous impulse must pass to the central nervous system before it can produce a reflex action. Demonstrate the difference in the physiology of smooth and striated muscles. Prove the existence of tonic contraction of muscle. Demonstrate the current of action in muscle or nerve. Give experimental evidence that the vagus connects with the nerve cells in the heart.

3. Show the function of the anterior spinal nerve-roots. Record with the artificial scheme pulse curves of low arterial tension and high arterial tension, and discuss their method of production. Construct a diagram showing the formation of the image in myopia. Prove that the extensibility of muscle is increased in tetanus. Demonstrate the limits of the refractory period and the existence of the compensatory pause. Prove that the demarcation current (current of injury) may act as a stimulus.

4. Show the effect of inhibition of the heart on arterial pressure in the frog. Demonstrate on muscle the different effect of sudden and of gradual increase in intensity of stimulus. Prove the discontinuous nature of tetanic contraction. Show the influence of temperature on the form of the contraction wave of skeletal muscle. Produce evidence that irritability is separable from conductivity. Show that the control of movements is localized at different levels of the spinal cord.

5. Determine the effect of stimulation of the vagus on the beat of the ventricle. Show that all contractions of heart muscle are maximal. Give experimental evidence that a nerve fibre may conduct impulses in both directions. Show that a constant stimulus may cause periodic contraction. Show the influence of fatigue on muscular contraction. Draw a construction showing the formation of the image in the indirect method of observing the retina.

6. Show the action of the sympathetic on the heart. Demonstrate the spreading of impulses in the central nervous system. Record curves showing the influence of changes in the aortic pressure on the interval between the beginning of ventricular contraction and the opening of the semilunar valves (in the artificial scheme). Show the segmental arrangement of the reflex apparatus. Construct a diagram showing the formation of the image in hypermetropia. Show the influence of an increase in peripheral resistance on the blood pressure in the frog.

7. Demonstrate that the cardiac systole is a simple contraction. Show the influence of load on the work done by skeletal muscle. Show where the more complicated coördinated reflex acts have their centres. Prove the independent irritability

of muscle. Show experimental proof of the law of contraction with weak, medium, and strong ascending currents. Make a record of minimal and maximal stimulation and show the effect of summation.

8. Show evidence that the ventricular contraction wave may be transmitted by muscular tissue. Prove that the excitability of a nerve is altered in the neighborhood of the anode and the cathode during the passage of the galvanic current. Secure a record of the effect of duration of stimulus on smooth muscle. Compare an isometric contraction with an isotonic contraction. Obtain from the artificial scheme of the circulation a characteristic pulse curve of aortic regurgitation and explain its production. Demonstrate and discuss the apparent purpose in reflex action.

The character of the written examination will be evident upon reading the following papers:

September, 1900

[Answer any four questions, but not more than four.]

1. Describe the coagulation of either blood or milk, stating both the physical and chemical phenomena.
2. Describe and draw an artificial scheme upon which the physical phenomena of the circulation of the blood can be demonstrated.
3. Give experimental evidence to show how the tetanic contraction of muscle is produced.
4. Describe fully the interchange between the air in the alveoli and the gases in the blood.
5. Give the complete course of any one of the ascending or descending tracts in the central nervous system.

6. Give experiments establishing the importance of any one of the internal secretions.

June, 1901

[Answer any four questions, but not more than four. The answer to any one question should not exceed three hundred words.]

1. Draw curves showing the changes of pressure in the auricle, ventricle, and aorta from the beginning of one auricular contraction to the beginning of the next. Add brief explanatory notes.
2. Give an account of the physiology of smooth muscle.
3. Discuss the chemistry of respiration.
4. Draw the motor area of the cortex and give evidence in support of the theory of cortical localization.
5. Write a sketch of the physiology of absorption.

September, 1901

[Answer any three questions, but not more than three. The answer to any one question must not exceed three hundred words. Mention, where possible, experimental evidence in support of your opinion. Matter not bearing directly on the question asked will count against the writer.]

1. Give an account of the physiology of ferments.
2. Describe the principal conducting paths in the spinal cord.
3. Give a general description of the vasomotor nervous system.
4. State experiments in support of a theory of accommodation in the eye.

III

THE ADVANCED COURSE

STUDENTS in the fourth year of the Medical School may elect advanced instruction, at present consisting of one hundred and sixty hours of laboratory study, in any field of physiology. It is to be presumed that such students desire additional work in physiology to fit them for some special field of medicine, for example the diseases of the nervous system; or they may wish to pursue physiology, pathology, or some other biological science as a profession. They will be received into the research laboratories of the department, and will carry on their studies side by side with the members of the Staff. The work will consist of fundamental experiments, the study of accessory data, and the reading of selected original investigations. The student will be guided by personal conferences with the professor in charge, and, if desirable, by informal lectures. He may also attend the optional lectures given in May (see page 39), in which each member of the Staff discusses the subjects which he has himself investigated.

This course counts toward the degree of Doctor of Medicine, and an examination, largely practical, will be required.

IV

PHYSIOLOGICAL RESEARCH

The laboratories are open at all times to students qualified to undertake research. The following investigations have been published during the past six years:

1896

Porter, W. T.: The vasomotor nerves of the heart. Boston medical and surgical journal, 1896, cxxxiv, pp. 39, 40.

Porter. W. T.: Weiteres über den Verschluss der Coronararterien ohne mechanische Verletzung. Centralblatt für Physiologie, 1896, ix, pp. 641–647.

Porter, W. T.: The use of anthropometrical measurements in schools. Educational review, 1896, pp. 126–133.

Porter, W. T.: Further researches on the closure of the coronary arteries. Journal of experimental medicine, 1896, i, pp. 46–70.

Porter, W. T.: A new method for the study of the intracardiac pressure curve. Journal of experimental medicine, 1896, i, pp. 296–303.

1897

Magrath, J. B., and H. Kennedy: On the relation of the volume of the coronary circulation to the frequency and force of the venticular con-

traction in the isolated heart of the cat. Journal of experimental medicine, 1897, ii, pp. 13–34.

PORTER, W. T.: 1. On the cause of the heart-beat. 2. The recovery of the heart from fibrillary contractions. 3. Note on the relation between the beat of the ventricle and the flow of blood through the coronary arteries. Journal of the Boston Society of the Medical Sciences, 1897, i, pp. 15–21.

PORTER, W. T.: On the cause of the heart-beat. Journal of experimental medicine, 1897, ii, pp. 391–404.

1898

PORTER, W. T.: The recovery of the heart from fibrillary contractions. American journal of physiology, 1898, i, pp. 71–82.

PRATT, F. H.: The nutrition of the heart through the vessels of Thebesius and the coronary veins. American journal of physiology, 1898, i, pp. 86–103.

PORTER, W. T.: The influence of the heart-beat on the flow of blood through the walls of the heart. American journal of physiology, 1898, i, pp. 145–163.

HYDE, I. H.: The effect of distention of the ventricle on the flow of blood through the walls of the heart. American journal of physiology, 1898, i, pp. 215–224.

CLEGHORN, A.: The reinforcement of voluntary muscular contractions. American journal of physiology, 1898, i, pp. 336–345.

CANNON, W. B.: The movements of the stomach studied by means of the Röntgen rays. American journal of physiology, 1898, i, pp. 359–382.

Cannon, W. B., and A. Moser: The movements of the food in the œsophagus. American journal of physiology, 1898, i, pp. 435–444.

Bancroft, F. W.: The venomotor nerves of the hind limb. American journal of physiology, 1898, i, pp. 477–485.

Muskens, L. J. J.: An analysis of the action of the vagus nerve on the heart. American journal of physiology, 1898, i, pp. 486–510.

Porter, W. T.: A new method for the study of the isolated mammalian heart. American journal of physiology, 1898, i, pp. 511–518.

1899

Porter, W. T.: The coördination of the ventricles. American journal of physiology, 1899, ii, pp. 127–136.

Stewart, C. C.: On the course of impulses to and from the cat's bladder. American journal of physiology, 1899, ii, pp. 182–202.

Baumgarten, W.: Infarction in the heart. American journal of physiology, 1899, ii, pp. 243–265.

Cleghorn, A.: The action of animal extracts, bacterial cultures, and culture filtrates on the mammalian heart muscle. American journal of physiology, 1899, ii, pp. 273–290.

Cleghorn, A.: The physiological action of extracts of the sympathetic ganglia. American journal of physiology, 1899, ii, pp. 471–482.

Woodworth, R. S.: Studies in the contraction of smooth muscle. American journal of physiology, 1899, iii, pp. 26–44.

Mathews, A. P.: The origin of fibrinogen. American journal of physiology, 1899, iii, pp. 53–85.

1900

Dearborn, G. V. N.: Notes on the individual psycho-physiology of the crayfish. American journal of physiology, 1900, iii, pp. 404–433.

Porter, W. T., and H. G. Beyer: The relation of the depressor nerve to the vasomotor centre. American journal of physiology, 1900, iv, pp. 283–299.

Porter, W. T., and W. Muhlberg: Experiments concerning the prolonged inhibition said to follow injury of the spinal cord. American journal of physiology, 1900, iv, pp. 334–342.

Franz, S. I.: On the methods of estimating the force of voluntary contractions and on fatigue. American journal of physiology, 1900, iv, pp. 348–372.

Cleghorn, A.: The physiological effects and the nature of extracts of sympathetic ganglia. Journal of the Boston Society of the Medical Sciences, 1900, iv, pp. 239–242.

1901

Mathews, A. P.: The spontaneous secretion of saliva and the action of atropine. American journal of physiology, 1901, iv, pp. 482–499.

McCurdy, J. H.: The effect of maximum muscular effort on blood-pressure. American journal of physiology, 1901, v, pp. 95–103.

Cleghorn, A., and C. C. Stewart: The inhibition time of a voluntary muscular contraction. American journal of physiology, 1901, v, pp. 281–286.

Cannon, W. B.: Cerebral pressure following trauma. American journal of physiology, 1901, vi, pp. 91–121.

V

THE SUMMER COURSE

The summer course in physiology will be given daily during the five weeks from June 30 to August 2, 1902, inclusive. This course will be found to be valuable to instructors of schools and colleges who seek experience in the teaching of physiology by laboratory methods. Students who wish to prepare themselves for the courses in the Medical School, or who may desire to recover ground lost by illness or other misfortune, will also find an opportunity here. The instruction will consist of fundamental experiments performed by the students themselves, and the study of accessory data. An informal lecture or conference will be given daily.

The fee for these thirty days of laboratory instruction, including the necessary material, will be forty dollars.

APPENDIX

APPARATUS

The following articles are required for the experiments upon muscle and nerve, the circulation, spinal cord and brain, physiological optics, and cutaneous sensations (pages 13–24). Additional lists for the subjects in preparation will be issued when the experiments are ready.

Adjustable plate, or nerve holder.[1]
Artificial scheme, see circulation scheme.
Balancing board, see board, balancing.
*Band, rubber, diameter 9 cm., for the head.
Beakers, 3, 7 × 6 cm.
Block, 8.6 × 8.6 × 1.6 cm., for +10 D lens, in artificial eye box.
——, 8.6 × 8.6 × 1.6 cm., for cylindrical +7 D lens, in artificial eye box.
——, 8.6 × 8.6 × 1.6 cm., for mirror, in artificial eye box.
——, 8.6 × 8.6 × 1.6 cm., for retina, in artificial eye box.
Board, balancing, 38.5 × 20.5 × 4.5 cm.
——, mesentery, with 6 fine pins.

[1] Articles marked * will be placed in the small wooden boxes.

Book, for laboratory notes, 21 × 17.5 cm., 180 pages.
——, for thesis, 21 × 17.2 cm., 32 pages.
Bottle, glass stopper, 9 × 3.7 cm., 45 c.c. curare; 2 drops should paralyze a frog in about 10 minutes.
——, 5 × 3 cm., 20 c.c., with 100 grams of mercury.
——, glass stopper, 13 × 5.3 cm., 135 c.c. normal saline.
——, glass stopper, 13 × 5.3 cm., 135 c.c. saturated solution zinc sulphate.
——, square, 7.5 × 4.3 × 4.3 cm., filled with 68 c.c. of 75 per cent glycerine tinged with eosin; cork flush with neck; in artificial box.
Bottles, 3, glass stoppers, 10 × 4.2 cm., 70 c.c., for solutions.
Bowl, earthenware, 18 × 5.5 cm., 1200 c.c.
Box, black, to cover retina.
——, 43.5 × 20.4 × 24 cm., to mount electrometer.
Boxes, 2, wooden, 12 × 8.7 × 5 cm.
*Brush, camel's-hair, for handling nerves.
Burner, Bunsen, with 150 cm. rubber tubing.
——, fish-tail, with perfect tip.
*Candlewick, 10 cm. long.
*Cannula, metal, for aorta, with 10 cm. rubber tube, and 3.5 cm. glass rod to fit tube.
Carbon dioxide generator, with wash bottle, marble, 20 per cent HCl in beaker, and connecting tubes.
Card, with no. 20 copper wire.
Cell, Daniell, amalgamated zinc, copper, porous cup, saturated solution copper sulphate, 5 per cent sulphuric acid.
Cells, 2 dry.
*Cement, colophonium 1 part, beeswax 4 parts, piece 2 × 2 × 2.5 cm.
Circulation scheme.
Clamp, curved iron.
——, 4 double iron.

Clamp, femur, or muscle clamp.
Clay, potter's kaolin in dish, 5.5 × 3.7 cm., moistened with 0.6 per cent NaCl solution.
Cloth, cotton, 30 × 40 cm.
*Collar button.
*Compressor, or cork clamp, or Gaskell clamp.
Cork, diameter 2 cm.
Cotton; fill beaker loosely.
Cylinder, cardboard, 20.5 × 5.5 cm., for kymograph paper.
——, cardboard box, 26 × 4 cm., for straws.
——, tin, cork plug, incense, in artificial eye box.
Diaphragm, 0.2 mm. aperture, in artificial eye box.
——, L aperture, in artificial eye box.
——, vertical and horizontal slit, in artificial eye box.
Dish, evaporating, diameter 8 cm.
——, paper, diameter 16 cm., for rocking key.
Dissecting case, with scissors, one large and one small forceps, and a seeker.
*Electrodes, brass, 1 flat, and 1 wire.
——, for inductorium.
*——, needle, 2 pair, each pair passed through a cork, diameter 1 cm.
——, 4 unpolarizable boots, with 4 spring clips, 4 zincs, and 4 no. 27 wires, 10 cm. long, in moist chamber.
——, 2 platinum, 5 × 0.5 cm.
——, 1 zinc, 7 by 0.5 cm.
Electromagnetic signal, see signal magnet.
Electrometer, capillary, 20 per cent sulphuric acid, with box, and curved iron clamp.
Ergograph, iron stand with spring, with adjustable rod, hand rest, and curved iron clamp.
Eye, artificial, see optical box.
——, artificial ophthalmoscopic, in artificial eye box.
Frog, sciatic nerve cut 4 days before use.

Frogs, medium size, average number for each student, 45.
——, large, average number for each student, 4.
Frog board, 4 clips.
Frog-heart manometer, see manometer, small mercury.
Funnel ring.
Galvanometer.
*Gas chamber, cork with 2 tubes and 2 electrodes, normal saline clay.
*Handles, 4 wooden, for pressure-hairs.
Heart-holder, wooden stand.
*Hooks, 2, S-shaped, one end sharp.
*——, 2 double.
Ice.
Incense, 4 pieces, 3 cm. long, in artificial eye box.
Inductorium.
Ink, black and red.
Interrupter wheel.
*Iron filings, 2 grams.
Jar, glass, battery, 20 × 17 cm., to hold frog.
Key, rocking, with paper dish.
——, simple.
Kymograph.
Lantern, 2 draw tubes.
Lens, convex, +2 D, in small envelope, in artificial eye box.
——, convex, +10 D, in wooden block, in artificial eye box.
——, concave, –2 D, in small envelope, in artificial eye box.
——, cylindrical, +2 D, in small envelope, in artificial eye box.
——, cylindrical, +7 D, in wooden block, in artificial eye box.
Lever, light muscle, with small scale pan and vertical pin.

Lever, heavy muscle, with large scale pan.
Ligature, thread, 100-yard spool.
*Magnet, bar.
Manometer, small mercury, with glass float and rubber tube.
Marble, for carbon dioxide generator.
Membrane, finest rubber, diameter 2 cm., for sphygmograph tambour.
*——, rubber dam, diameter 5 cm., for sphygmograph thistle tube.
*Menthol pencil.
Mercury cup, for vibrating reed.
Mesentery board, see board, mesentery.
Metronome, one in each room.
*Micrometer ocular.
Microscope, with jointed stand for horizonal adjustment.
*Millimetre paper, strip 15×1.5 cm.
Mirror, concavo-convex, in wooden block, in artificial eye box.
——, plane, glass, 5×5 cm., in artificial eye box.
Moist chamber, with 4 unpolarizable boots, 4 clips, 1 femur clamp, and glass shade.
Mounting rod, for boot electrodes.
Muscle clamp, see clamp, femur.
—— lever, heavy, see lever, heavy muscle.
—— lever, light, see lever, light muscle.
—— warmer, with thermometer, lead shot, and ice.
Nerve holder, see adjustable plate.
Optical box, see also
block, holding +10 D lens.
——, holding cylindrical +7 D lens.
——, holding concavo-convex mirror.
——, holding retina.
bottle, square, filled with 75 per cent glycerine tinged with eosin; cork flush with neck.
cover, plate glass.

Optical box (*continued*) —
cylinder, tin, with cork plug.
diaphragm, 0.2 mm. aperture.
——, L aperture.
——, vertical and horizontal slit.
incense, 4 pieces 3 cm. long.
mirror, plane, silvered glass.
ophthalmoscopic eye.
screen, 1 cm. diameter.
slide, glass, to cover window.
——, ground glass.
*Paper, black, 1 × 1 cm., stroboscopic method.
——, coördinate, 10 × 10 cm.
——, filter, 1 sheet, 50 × 50 cm.
*——, filter, 5 × 5 cm., soaked in starch paste with potassium iodide.
——, glazed on one side, in cardboard case, 25 sheets, 54.8 × 18.5 cm., gummed 0.8 cm. at one end.
——, paraffin, 10 × 7 cm.
——, for written tests, 24.5 × 19.5 cm., printed.
*——, for writing-points, 5 × 5 cm.
Paramecia.
*Pins, 6, for mesentery.
Pipette, glass tube, 20 cm. long, diameter 0.6 cm., drawn out.
——, fine glass.
——, rubber bulb.
Plate, glass, 12.8 × 10.3 cm.
——, glass cover, for artificial eye box.
Plethysmograph tube, with rubber collar 4 cm. long, rubber tubing, and T-tube.
Pole changer, see key, rocking.
Rabbit, uninjured, in rabbit holder, for heart reflex.
Reed, vibrating, 20 cm.
Rheochord.
*Ring, brass, 0.1 gram.

*Ring, 2 straw fasteners.
*Rod, glass, 3.5 cm., for aortic cannula tube.
——, glass, L-shaped, Exp. salts on heart-muscle.
——, stirring, 20 cm. long, end drawn out.
——, wooden, 8.5×0.6 cm.
Scale pan, large.
—— pan, small.
Shellac dissolved in 96 per cent alcohol.
*Shot, lead, 1 gram, split.
Signal magnet.
*Slide, glass, 7.6×2.6 cm.
——, glass, 7.6×3.9 cm., in artificial eye box.
——, ground glass, 7.6×3.9 cm., in artificial eye box.
Sodium chloride, crystals in salt mouth, 30 c.c., bottle.
Solutions,[1]
amyl nitrite.
acetic acid (strong).
alcohol.
ammonia, NH_3.
atropine, 0.5 per cent.
Biedermann's fluid,
sodium chloride, $NaCl$, 5 grams.
disodium hydrogen phosphate, Na_2HPO_4, 2 grams.
sodium carbonate, Na_2CO_3, 0.4 gram.
water, H_2O, 1000 c.c.

[1] The composition of each solution is written upon as many tags as there are pairs of students. The writing is coated with shellac dissolved in alcohol. Experience has shown that not more than three solutions are needed at any one laboratory exercise. The necessary quantity of the liquids is transferred from large stock bottles to three small bottles, upon which the corresponding tags are placed. Each tag has a metal ring which slips readily over the neck of the bottle. At the close of the exercise the tags are stored away, and the bottles carefully washed.

Solutions (*continued*) —
calcium chloride, $CaCl_2$, 1 per cent.
copper sulphate, $CuSO_4$, saturated solution.
distilled water, H_2O.
ether.
hydrochloric acid, HCl, 20 per cent.
muscarine (trace).
nicotine, 0.2 per cent.
potassium chloride, KCl, 5 per cent.
—— chloride, KCl, 0.9 per cent.
Ringer's fluid,
calcium chloride, $CaCl_2$, 0.0026 gram.
potassium chloride, KCl, 0.035 gram.
sodium chloride, NaCl, 0.7 gram.
water, H_2O, to make 100 c.c.
sodium carbonate, Na_2CO_3, 1 per cent.
—— chloride, NaCl, saturated solution.
—— chloride, NaCl, 0.6 per cent, "normal saline."
—— chloride, NaCl, 0.75 per cent.
strychnine sulphate, 0.5 per cent.
sulphuric acid, H_2SO_4, 5 per cent.
—— acid, H_2SO_4, 0.2 per cent.
veratrine acetate, 1 per cent.
Sphygmograph tambour, with rubber tubing, T-tube, fine straw, finest rubber membrane, thistle tube, rubber dam, and collar button.
Stand, two iron, with 4 clamps.
——, wooden.
Straw, fine, for sphygmograph tambour.
——, large, 36 cm. long, with platinum wire soldered to thin copper wire.
Straws, large, 20 cm. long, 3 in cardboard case.
Tags, written and shellacked, one for each solution except curare, normal saline, and saturated solution zinc sulphate.
Thermometer, diameter not over 0.8 cm.

*Thread, silk, 50 cm.
Tin foil, see paper.
Tortoise, average number for each student, 1.
Towel, small.
Tracing holders, 3.
Tuning fork.
Vertebral saw.
Volume tube, 2 corks with hook electrode.
Wash bottle, for carbon dioxide generator.
Web board; may use mesentery board.
*Weights, 10 one-gram in box.
——, 100 ten-gram in large scale pan.
Wire gauze, 10 × 10 cm.
Wire, 300 cm., fine copper, no. 33, on spool.
——, copper, 10 cm.
——, iron, 10 cm.
——, zinc, 10 cm.
Wires, copper, 13 no. 25, 60 cm. long, on spool.
——, copper, 2 no. 25, 150 cm. long, coiled.
——, connecting, for lantern, with plug.
Work adder.

Form F.

[Requisition blank.]

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
.........................., 190....

The undersigned desires the following supplies:

....

....

Room..................
(Signed)...
Number...............

Form G.

[First issue of apparatus.]

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
February 8, 1902.

The undersigned students have received this first issue of apparatus, for experiments upon the methods of electrical stimulation of muscle and nerve, chemical and mechanical stimulation.[1]

Adjustable plate.
Beakers, 3.
Bottle, with curare.
——, with 0.6 per cent NaCl.
——, with saturated $ZnSO_4$.
——, with Hg.
Boxes, 2 small wooden.
Bowl.
*Brush, camel's-hair.
Burner, Bunsen, and tubing.
——, fish-tail.
Cells, 2 dry.
*Cement, colophonium.
Clamp, curved iron.
——, 4 double iron.
——, femur, see muscle clamp.
Clay, in glass dish.
*Compressor (Gaskell clamp).
Cork.
Cork clamp.
Cylinder, cardboard, with 25 sheets kymograph paper.
——, cardboard box, with 3 straws.
Dish, paper, for rocking key.
*Electrodes, brass, one flat and one wire.
——, for inductorium.

[1] Articles marked * will be found in the small wooden boxes.

*Electrodes, 4 needle, with 2 small corks.
——, 4 unpolarizable (4 boots, 4 spring clips, 4 zincs, and 4 connecting wires, in moist chamber).
Electromagnetic signal, see signal magnet.
Electrometer mounted on box.
Frog board with 4 clips.
Funnel ring.
*Hooks, S-shaped, 2.
*——, double, 2.
Inductorium.
Jar, battery.
Key, rocking, with paper dish.
——, simple.
Kymograph.
Lever, light muscle, with vertical pin.
Ligatures, thread, on spool.
*Micrometer ocular.
Millimetre paper.
Moist chamber, glass cover.
Mounting rod for unpolarizable electrodes.
Muscle clamp.
Nerve holder, see adjustable plate.
Paper, coördinate.
——, filter.
*——, for writing points.
——, glazed, 25 sheets in cardboard case.
Pipette.
——, fine glass.
——, with rubber bulb.
Plate, glass.
Pole-changer, see key, rocking.
Porcelain dish.
Rheochord.
*Ring, wire straw fastener, 2.
Rod, glass.
Scale pan, small.
Signal magnet.

*Slide, glass.
Stands, 2 iron, and 4 clamps.
Straws, 3 in case.
Tracing holders, 3.
Tuning fork.
*Weights, 10 ten-gram.
Wire, 300 cm. fine copper, on spool.
——, copper, 10 cm.
——, zinc, 10 cm.
Wires, copper, 13 two-ft. each, 1 five-ft.
Wire gauze.

(Signed)......................................

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Desk..................Room.............

Form H.

[Second issue of apparatus.]

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
......................................1902.

The undersigned students have received this second issue of apparatus, comprising the additional pieces necessary for experiments upon irritability and conductivity, electromotive phenomena of muscle and nerve, and change in form.

Candlewick.
Carbon dioxide generator, with marble, wash bottle, and connecting tubes.
Cotton.
Ergograph, with adjustable rod, and hand rest.
Gas chamber, cork with 2 tubes and 2 electrodes.
Heart holder.
Interrupter wheel.
Lever, heavy muscle (rigid muscle lever).
Muscle warmer.

Rubber band.
Scale pan, large, with 90 ten-gram weights.
Shot, lead, split.
Wash bottle, for carbon dioxide generator.
Weights, 10 one-gram.
——, 100 ten-gram, in scale pan.
Work adder.

(Signed)....................................

....

Desk..................Room.............

Form I.

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
March 13, 1902.

The following apparatus has been returned by students....................................and....................................

Room...................Desk............

[First return list.]

Adjustable plate.
Bottle, with saturated $ZnSO_4$.
Candlewick.
Carbon dioxide generator, with marble, wash bottle, and connecting tubes.
Cork clamp.
Dish with clay (kaolin).
Electrodes, 4 needle, with 2 small corks.
——, 4 unpolarizable (4 boots, 4 spring clips, 4 zincs, and 4 connecting wires).
Electrometer, mounted on box.
Ergograph, with adjustable rod, and hand rest.
Gas chamber.
Moist chamber, glass cover.
Muscle clamp.

Lever, heavy muscle.
——, light muscle.
Muscle warmer.
Nerve holder, see adjustable plate.
Rheochord.
Scale pan, large.
—— pan, small.
Tuning fork.
Wash bottle, for carbon dioxide generator.
Weights, 10 one-gram.
——, 100 ten-gram.
Work adder.

(Signed)..

For Department of Physiology.

Form J.

[List of apparatus liable to be broken.]

Beakers	20 cents
Boot electrodes	10 "
Capillary tube on electrometer	25 "
Cover to moist chamber	20 "
Gas chamber	10 "
Glass plate	2 "
Jar of Daniell cell	25 "
Pipettes	3 "
Stirring rod	2 "
Tip to gas burner	2 "

Date Due

Porter

Physiology at Harvard